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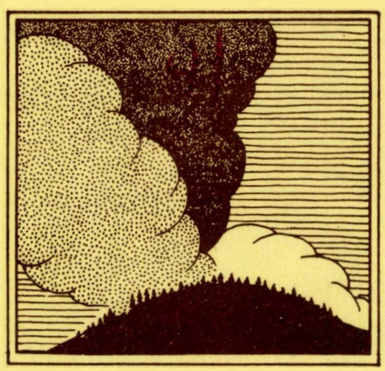
CROWN CHARACTERISTICS OF SEVERAL HARDWOOD TREE SPECIES



DIVISION OF FIRE RESEARCH
FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

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CROWN CHARACTERISTICS
OF SEVERAL HARDWOOD TREE SPECIES
-- Relations between Weight of Crown, Branchwood --
and Foliage, and Stem Diameter

by

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SUMMARY

This study was made to investigate the relation between the physical characteristics of crown and stem of several broadleaf tree species. The results are presented in a number of generalized relations correlating these characteristics.

Fifty-seven trees consisting of six species selected from a site class II or better mixed-hardwood forest were analyzed for weight of foliage, branchwood, and crown. The calculated dry weights of foliage, branchwood, and crown were correlated with stem diameter at breast height and stem diameter at base of live crown. Separate correlations were made for each species. High degrees of correlation were found in each of these relations with stem diameter at base of live crown exhibiting the better results. Higher degrees of correlation were obtained for most species when the height of crown variable was combined with the dry weight data and correlated with diameter at base of live crown.

The accuracy of estimating dry weights of foliage, branchwood, and crown varied in each of the relations developed in this study. Foliage estimations can be determined with equal accuracy with each of the three relations. Estimating dry weight of branchwood from the diameter base of live crown relation, with or without the height of crown variable, gave more accurate results than with the relation using stem diameter at breast height. Dry weight of crown estimations were most accurately determined when the height of crown variable was included in the dry weight relation.

For the species studied geometrical similarity of tree crowns was found for trees of all sizes and crown lengths. Because of this, the dry weight of crown relation can be used for any portion of the tree crown regardless of tree size or crown length.

From the results presented in this study dry weight of branchwood averaged 2-6 times heavier than dry weight of foliage in the six species of hardwoods studied.

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INTRODUCTION

The relation between the physical characteristics of tree crown and stem is necessary for the development of a method which predicts tree breakage and uprooting from shock-wave winds of the type associated with nuclear weapons. Information on the dry weight of crown is required for estimating aerodynamic drag of broadleaf trees of all sizes and shapes. This study was made to relate dry weight of foliage, branchwood, and total crown[1/] of several broadleaf species to stem diameter and crown length.

The present study is similar to a companion study on crown characteristics of several coniferous tree species (10)[2/]. These studies are two of a number of basic studies (2,5,6,9) investigating physical and mechanical properties of trees in order to develop a method of predicting tree breakage and uprooting from strong winds.

Wind causes trees to bend, break, and uproot through aerodynamic drag on foliage, branchwood, and to a lesser extent on main stem surfaces. Drag force has been related to dry weight of foliage for several broadleafs (5) and to dry weight of crown for several species of conifers (9). Both dry weight of foliage and dry weight of crown are indirect measures of crown surface area. Knowledge of how the crown weight varies with stem diameter, crown geometry and other conditions is necessary in estimating drag of different size trees with crowns of all sizes and shapes that may be found in a forest stand.

Although primarily concerned with prediction of tree breakage and uprooting, the relations developed in this study should find other applications. Knowledge of foliage weight could be used in studies in watershed management to check and supplement previous work on litter accumulation, infiltration, and transpiration. Data on crown weight should prove useful in watershed management, forest management, and fire control in studies of snow interception by tree crowns, amount of logging slash or potential fuel volume in tree crowns.

1/ Total crown includes the branchwood and foliage comprising the crown, but does not include the stem.

2/ Underlined numbers in parenthesis refer to Literature Cited, page 33.

PREVIOUS STUDIES

Numerous studies have been made on the quantitative variations of foliage for broadleaved and coniferous tree species, however, little is known concerning weight of branchwood or total crown. Foliage has been studied intensively by area, volume, weight, and number, all of which are closely related. Quantities have been determined both by sampling and by measurement of total foliage. Since few investigators have correlated these measures with tree-stem characteristics, little of the published material is directly applicable to the present study.

The correlation between surface area of foliage and weight of foliage has been well established by studies on both conifers and hardwoods (1,8,11). In these studies surface area was found to be directly proportional to dry foliage weight, and for any one species the ratio of leaf area to dry weight of leaves was found nearly constant.

Among the first attempts to investigate the relation between crown weight and stem dimensions was a study made on fruit trees (12). In this study a high correlation was found between weight of crown and circumference of the trunk.

The relation between leaf weight and diameter of individual trees has been studied for a number of tree species in different stands representing a variety of locations, sites, and ages (3,4). In all cases the correlation was found to be linear when data were plotted on logarithmic paper and could be represented by the equation

$$W = a(D)^b$$

where (W) is dry leaf weight and (D) is diameter at breast height (d_{bh}). It was concluded that this relation was applicable to trees of different sizes, crown densities, crown classes, and ages, at least up to the age of culmination of growth and beyond that for tolerant species in all-aged stands. The same relation was used in another study to correlate number of leaves with both branch diameter and tree diameter for individuals of white, scarlet, and black oak (7).

PROCEDURE

Data for this study were collected in the summer of 1952 from a site class II or better mixed-hardwood forest in the Pisgah National Forest, North Carolina. The species included in this study are given in table 1. Trees were selected on the basis of dominance, uniformity and fullness of crown, good stem form, and freedom from defects. Specimens having the excurrent type of branching similar to conifers were preferred. Trees varied in diameter from 2 to 23 inches and in height from 15 to 100 feet.

Table 1.--Common and botanical names of test trees

Common name	Botanical name	Tree numbers
Silver maple	Acer saccharinum L.	1-8
Sweet birch	Betula lenta L.	9-18
Pignut hickory	Carya glabra Sweet	19-28
American beech	Fagus grandifolia Ehrh	29-36
Yellow-poplar	Liriodendron tulipifera L.	37-48
Scarlet oak	Quercus coccinea Muenchh.	49-57

For each tree selected for analysis diameter breast height,[3] total height, and height to base of live crown were measured. Height measurements were determined by repeated Abney level observations and checked by direct measurement of the stem after falling. The crown length was divided on the standing tree into 1 to 3 sections depending on tree size, percent crown length increasing from the tip down (see figures 1 and 2). The tree was then pruned of dead branches, and the area around each tree was cleared of all litter.

Each section of the crown was separately pruned of branches beginning with the lower section. The crown material was weighed, and moisture samples of foliage and branchwood were immediately collected at random from each section. The foliage and branchwood moisture

[3] Breast height is 4 1/2 feet above ground level.

Figure 1.--Yellow-poplar 20 inches in diameter at breast height and 60 percent crown prior to analysis.

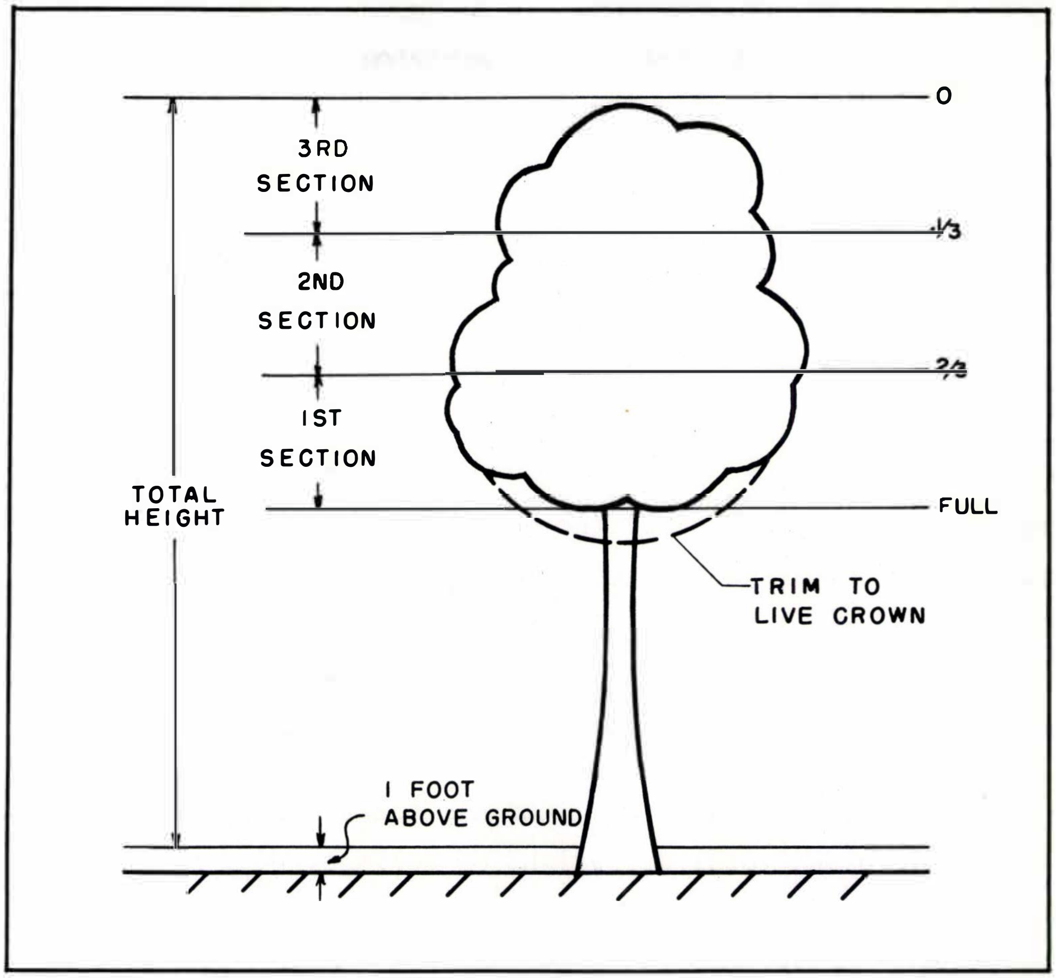

Figure 2.--Tree division for crown analysis

samples were separately kept in airtight moisture cans. About one-third of each crown section was set aside and stripped for branchwood and foliage analyses. Total sections of easily stripped species and crowns of smaller trees for all species were completely stripped. The branchwood and foliage were weighed separately following stripping, and another moisture sample was taken. Moisture samples were later oven-dried at $100^{\circ}C$ for 48 hours.

After the crown was completely removed the stem was felled and cuts were made at the base of each crown section. Average diameter inside bark at each cut and the stem length were measured and recorded.

The dry weight of foliage and the dry weight of branchwood in each crown section was determined, respectively, by the equations[4]

$$W'_{df} = \frac{k\, W'_{gc}}{k\,(1 + M_f) + (1 + M_b)} \qquad (1)$$

and

$$W'_{db} = \frac{W'_{gc}}{k\,(1 + M_f) + (1 + M_b)} \qquad (2)$$

where

$$k = \frac{w_{df}}{w_{db}} \qquad (3)$$

Equation (3) is an expression of the dry weight of foliage to branchwood determined from a sample taken from each crown section. Values of w_{df} and w_{db} were calculated from the basic equation

$$w_d = \frac{w_g}{1 + m} \qquad (4)$$

The dry foliage values, W'_{df}, of all crown sections (equation (1)) were added to give the total dry weight of foliage, W_{df}, of the tree. Similarly, the dry branchwood values, W'_{db}, of all crown sections (equation (2)) were added to give the total dry weight of branchwood, W_{db}, of the tree. The total dry weight of crown, W_{dc}, was obtained by combining W_{df} and W_{db}, i.e.,

$$W_{dc} = W_{df} + W_{db} \qquad (5)$$

RESULTS

Physical characteristics of crown and stem for each sample tree and calculated dry weights for total crown and its components--branchwood and foliage--are presented in table 6, Appendix.

4/ Nomenclature given on page 35.

Dry weights of foliage, branchwood, and crown were correlated by species with stem diameter at breast height and stem diameter at base of live crown. Curves similar to those presented in figures 3, 4, 5, and 6 were obtained. Regression equations of the form[5/]

$$W = a(d_{bh})^b \qquad (6)$$

and

$$W = a(d_c)^b \qquad (7)$$

respectively, were calculated for each species. Equation constants and statistics for these relations are presented in tables 2-4.

Heights of crown (H_c) were combined with the dry weights of foliage, branchwood, and crown of individual trees and plotted by species against the diameter at the base of live crown. Curves similar to those presented in figures 7, 8, and 9 were obtained. Equation constants and statistics for each regression

$$WH_c = a(d_c)^b \qquad (8)$$

are tabulated in tables 2-4.

For the purpose of evaluating geometrical similitude of tree crowns, dry weight of crown data for each crown section of individual trees of each species (see table 6, Appendix) were correlated using equation (8). In table 5 are tabulated equation constants and statistics for these correlations along with the number and range of data.

DISCUSSION

From the curves presented in figures 3-9 it can be seen that the dry weight relations for foliage, branchwood, and crown have linear trends. In each case a high degree of correlation was found when these relations were statistically analyzed (see tables 2-4).

5/ Nomenclature given on page 35.

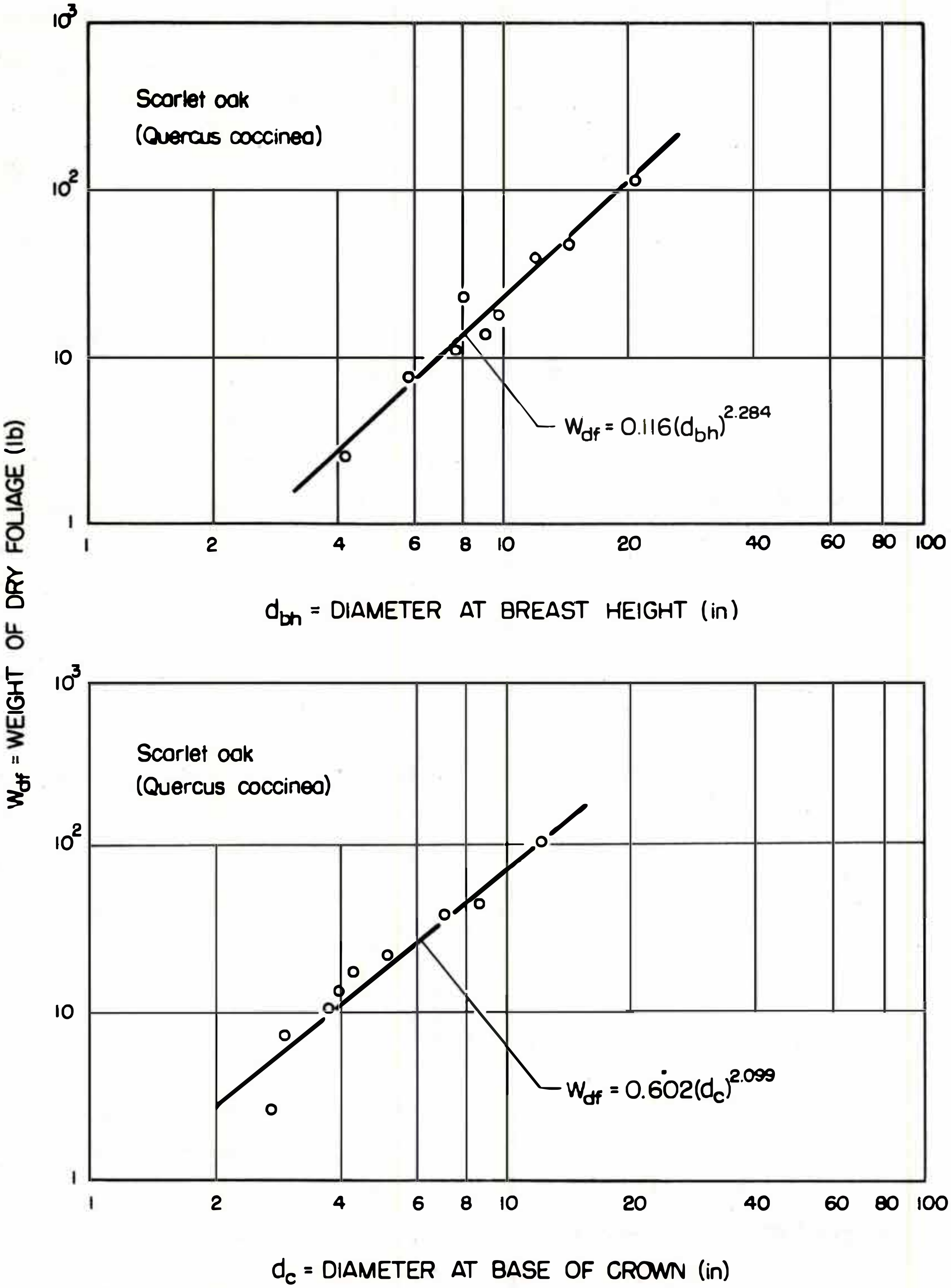

Figure 3.--Dry weight of foliage--stem diameter relations for scarlet oak

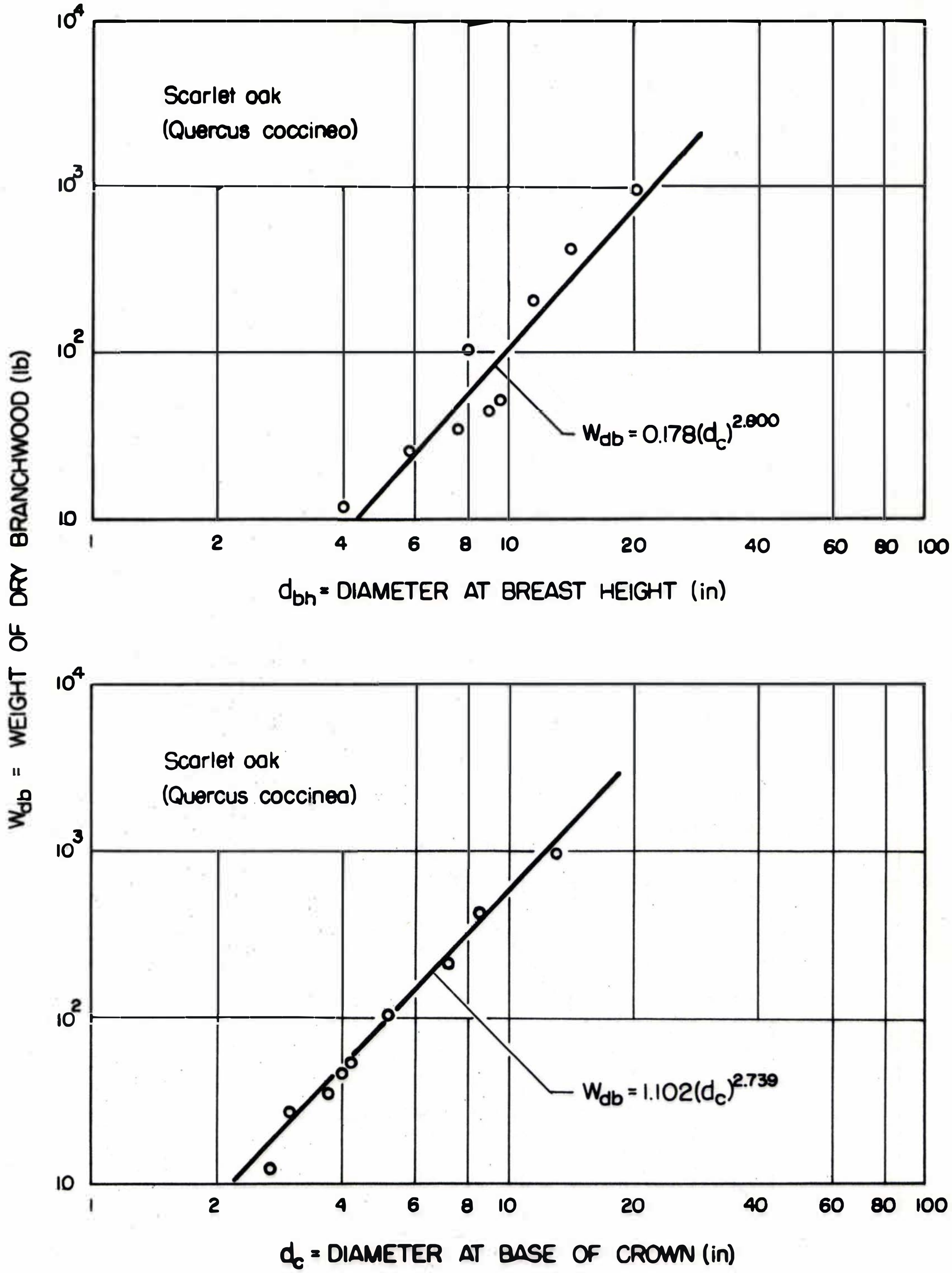

Figure 4.--Dry weight of branchwood--stem diameter relations for scarlet oak

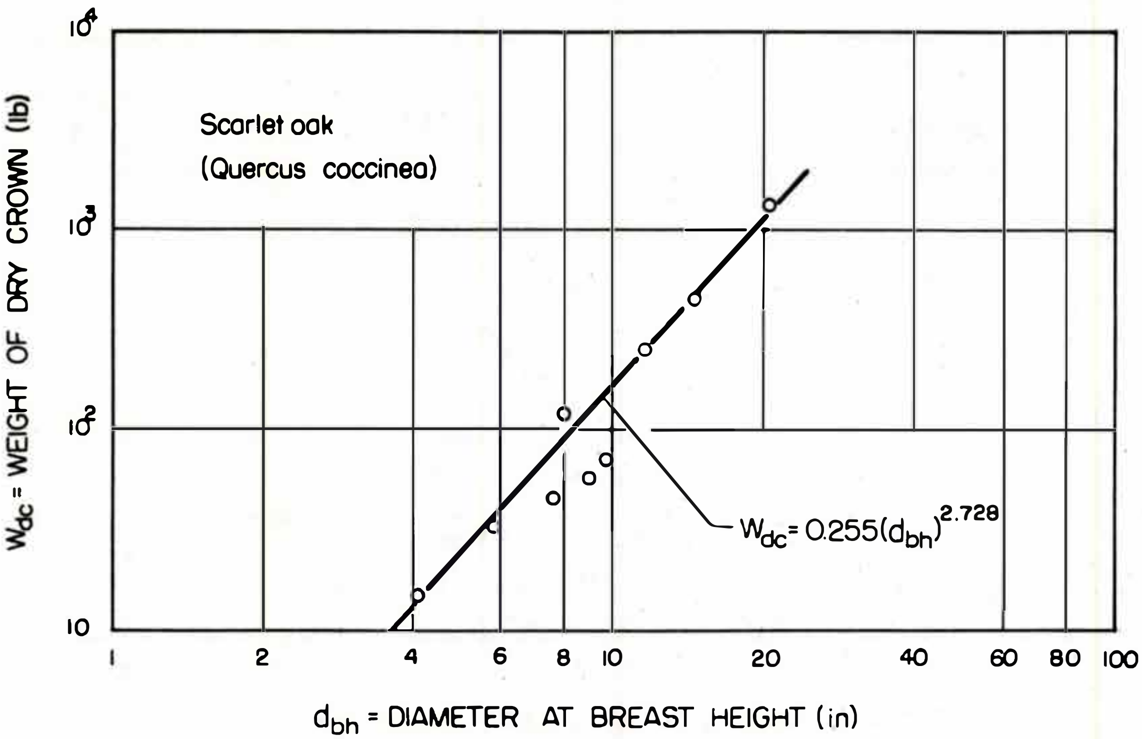

Figure 5.--Dry weight of crown--diameter breast height relation for scarlet oak

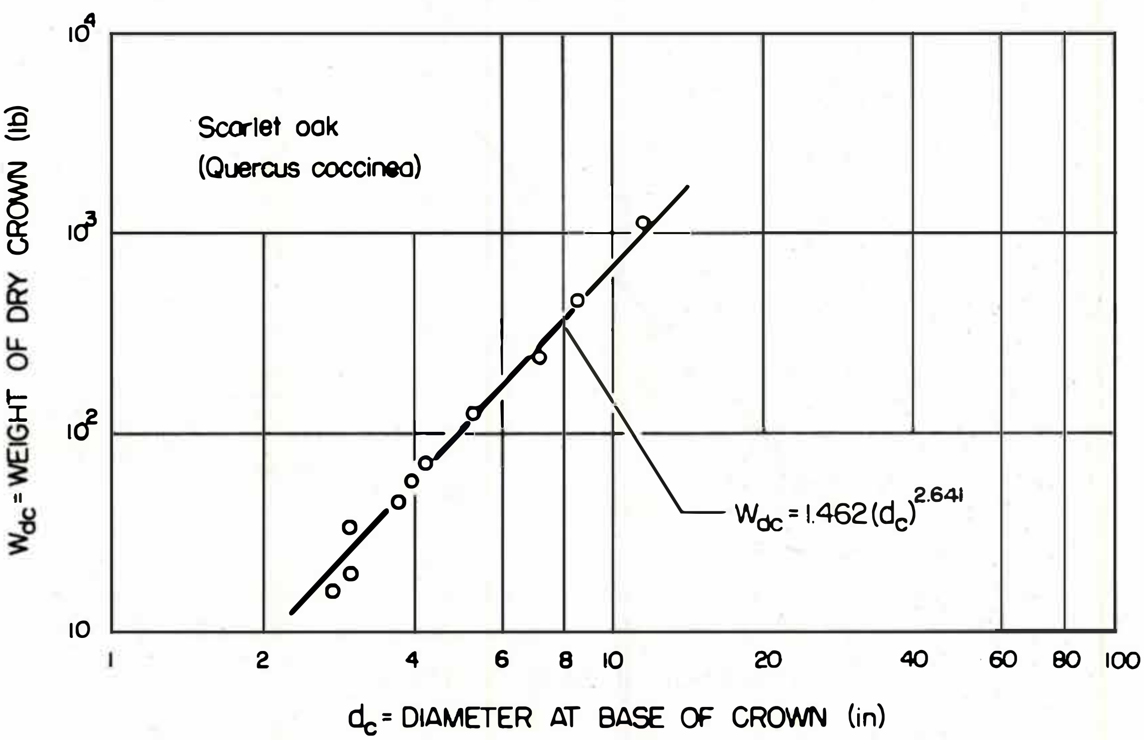

Figure 6.--Dry weight of crown--diameter base of crown relation for scarlet oak

Table 2.--Regression constants and statistics for dry weight of foliage relations, full-crown[1]

Tree species	Number of trees	Relation: $W_{df} = a(d_{bh})^b$				Relation: $W_{df} = a(d_c)^b$				Relation: $W_{df}H_c = a(d_c)^b$			
		Constants		Statistical measures		Constants		Statistical measures		Constants		Statistical measures	
		a	b	r[2]	S_{yx}[3]	a	b	r[2]	S_{yx}[3]	a	b	r[2]	S_{yx}[3]
Silver maple	8	0.066	2.544	0.932	71	0.291	2.279	0.970	45	4.092	2.704	0.991	27
Sweet birch	10	0.243	1.928	0.962	35	0.399	2.152	0.985	21	3.579	2.901	0.977	36
Pignut hickory	10	0.101	2.372	0.983	32	0.645	2.060	0.976	38	6.410	2.749	0.991	31
American beech	8	0.311	2.048	0.978	27	0.762	1.776	0.989	19	9.279	2.384	0.990	24
Yellow-poplar	12	0.188	1.775	0.961	36	0.446	1.829	0.939	45	4.974	2.456	0.986	42
Scarlet oak	9	0.116	2.284	0.976	25	0.602	2.099	0.960	33	6.559	2.656	0.978	31

1/ Nomenclature given on page 35.
2/ Coefficient of correlation.
3/ Standard error of estimate in percent.

Table 3.--Regression constants and statistics for dry weight of branchwood relations, full-crown[1]

Tree species	Number of trees	Relation: $W_{db} = a(d_{bh})^b$				Relation: $W_{db} = a(d_c)^b$				Relation: $W_{db}H_c = a(d_c)^b$			
		Constants		Statistical measures		Constants		Statistical measures		Constants		Statistical measures	
		a	b	r[2]	S_{yx}[3]	a	b	r[2]	S_{yx}[3]	a	b	r[2]	S_{yx}[3]
Silver maple	8	0.341	2.564	0.981	33	1.154	2.208	0.982	33	24.750	2.633	0.992	25
Sweet birch	10	0.875	2.159	0.935	54	1.470	2.437	0.969	36	13.153	3.188	0.964	53
Pignut hickory	10	0.329	2.603	0.974	44	2.421	2.290	0.980	39	24.314	2.984	0.990	36
American beech	8	0.560	2.668	0.984	30	2.270	2.282	0.982	32	27.707	2.890	0.992	26
Yellow-poplar	12	0.693	1.807	0.961	36	1.420	1.970	0.993	15	15.845	2.597	0.994	19
Scarlet oak	9	0.178	2.800	0.951	47	1.102	2.739	0.995	14	11.124	3.295	0.997	13

1/ Nomenclature given on page 35.
2/ Coefficient of correlation.
3/ Standard error of estimate in percent.

Table 4.--Regression constants and statistics for dry weight of crown relations, full-crown[1]

Tree species	Number of trees	Relation: $W_{dc} = a(d_{bh})^b$				Relation: $W_{dc} = a(d_c)^b$				Relation: $W_{dc}H_c = a(d_c)^b$			
		Constants		Statistical measures		Constants		Statistical measures		Constants		Statistical measures	
		a	b	r[2]	S_{yx}[3]	a	b	r[2]	S_{yx}[3]	a	b	r[2]	S_{yx}[3]
Silver maple	8	0.413	2.558	0.977	37	2.065	2.217	0.983	32	29.365	2.635	0.994	21
Sweet birch	10	1.133	2.118	0.943	48	1.873	2.389	0.975	32	16.757	3.141	0.968	48
Pignut hickory	10	0.420	2.582	0.979	39	3.040	2.271	0.983	35	30.212	2.960	0.990	35
American beech	8	0.837	2.552	0.987	25	2.922	2.218	0.986	27	35.992	2.822	0.994	7
Yellow-poplar	12	0.933	1.781	0.973	29	1.907	1.936	0.995	16	21.236	2.564	0.997	14
Scarlet oak	9	0.255	2.728	0.960	41	1.462	2.641	0.994	16	15.916	3.198	0.997	14

1/ Nomenclature given on page 35.
2/ Coefficient of correlation.
3/ Standard error of estimate in percent.

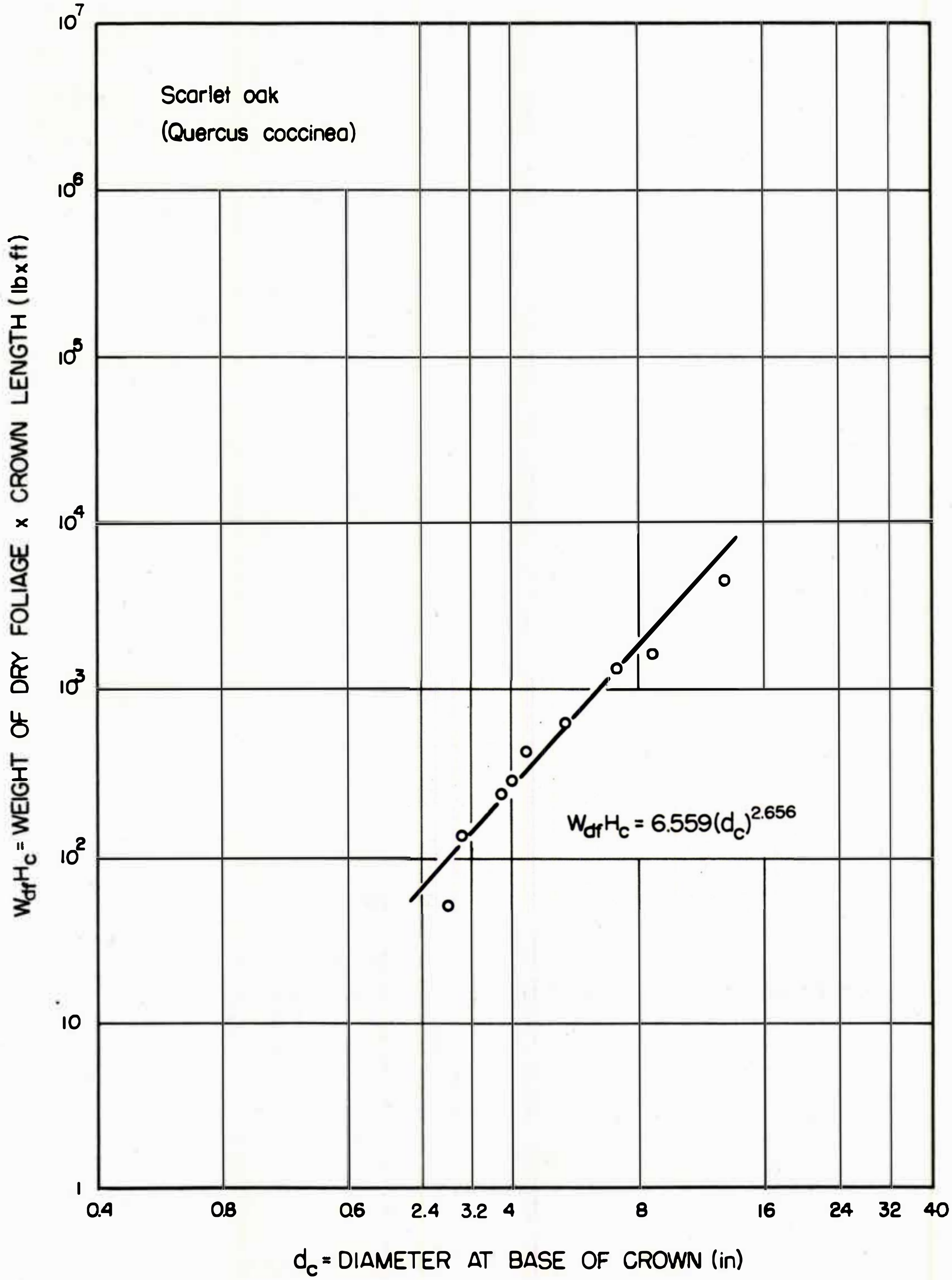

Figure 7.--Dry weight of foliage-crown length--diameter base of crown relation for scarlet oak

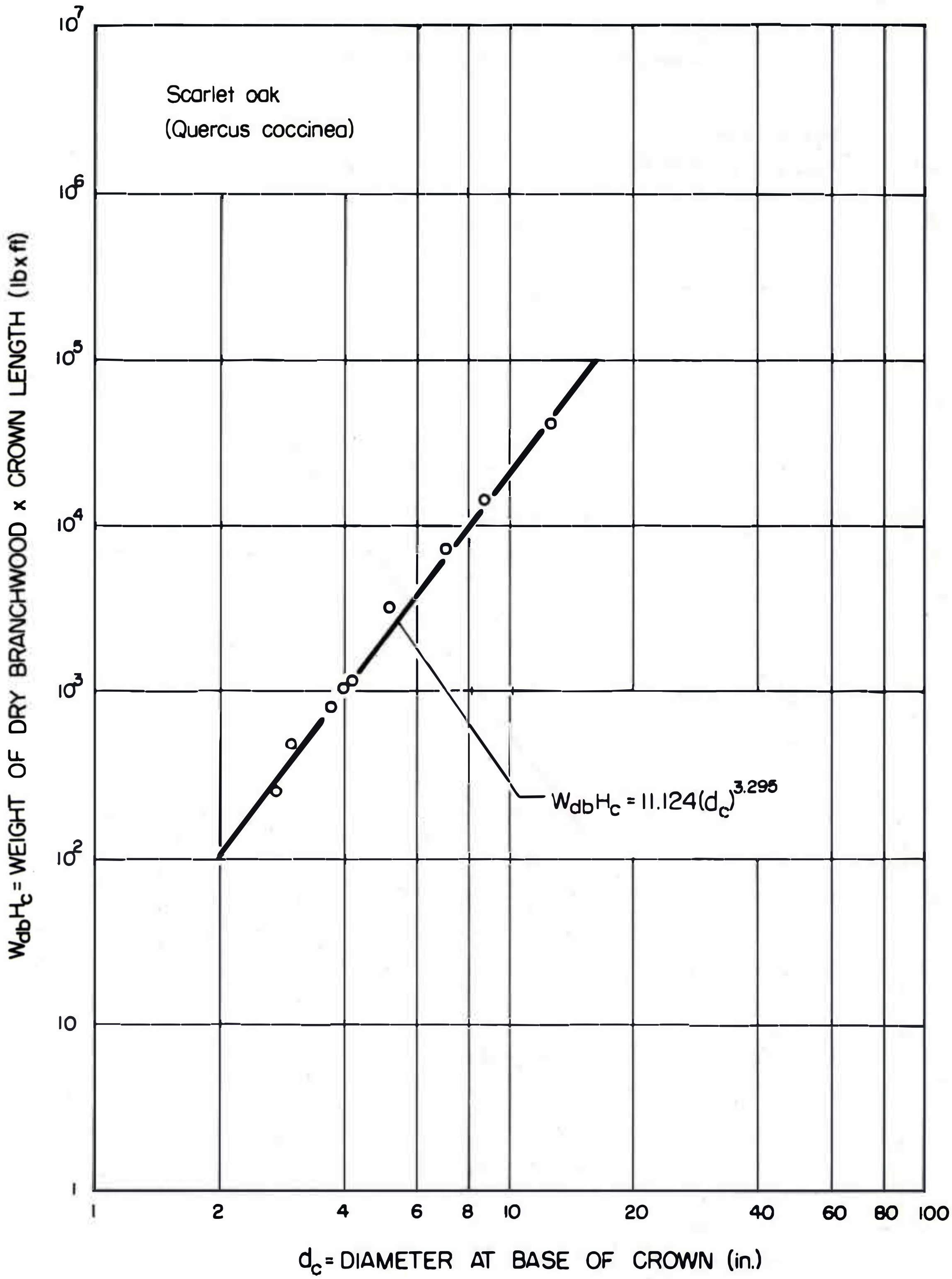

Figure 8.--Dry weight of branchwood-crown length--diameter base of crown relation for scarlet oak

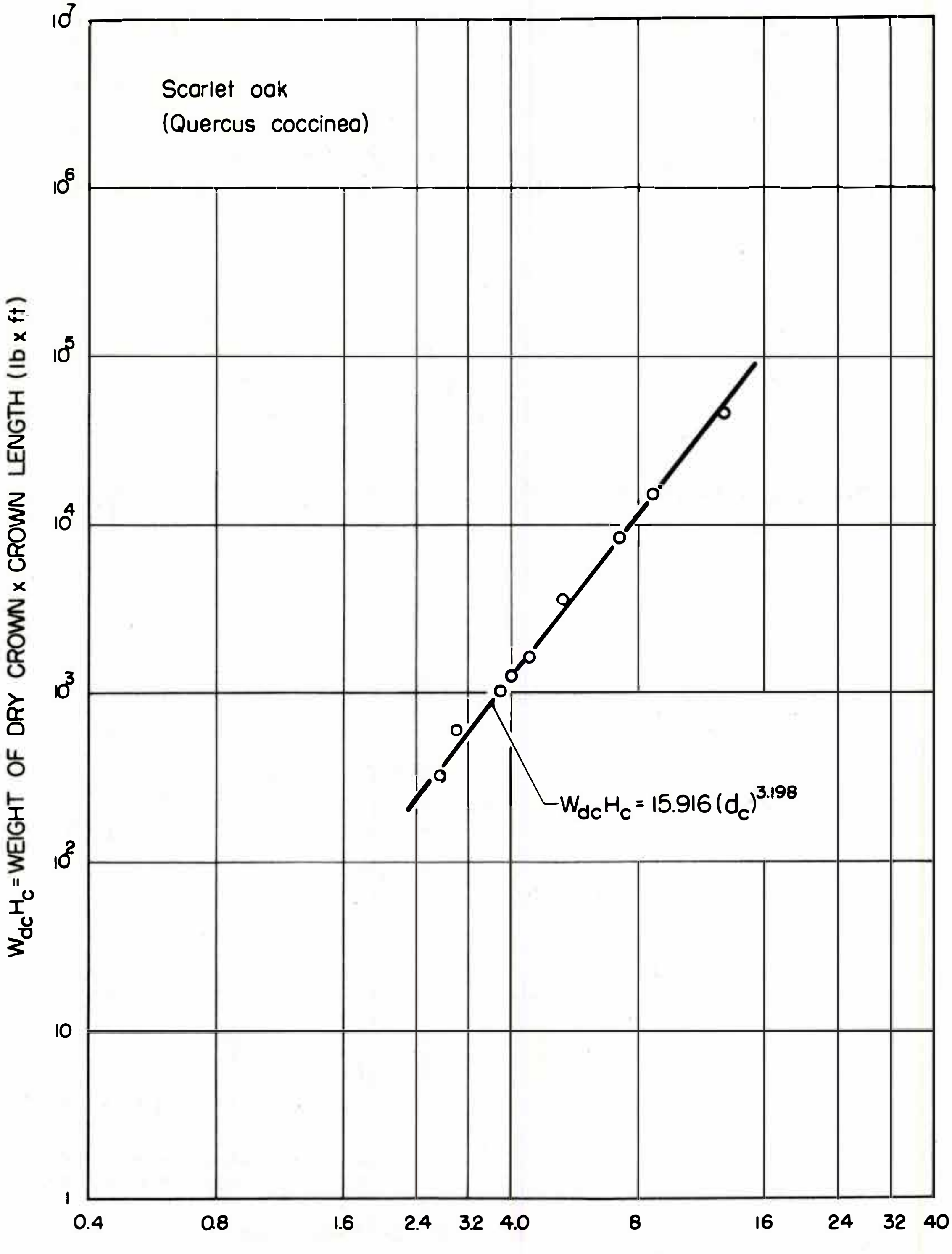

Figure 9.--Dry weight of crown-crown length--diameter base of crown relation for scarlet oak

Table 5.--Regression constants and statistics for dry weight of crown relations, all crown lengths[1]

Tree species	Number of trees	Number of data	Range of data: Base crown diameter d_c (in.)	Range of data: Crown length H_c (ft)	Range of data: Crown weight W_{dc} (lbs)	Relation: $W_{dc}H_c = a(d_c)^b$ Constants: a	Constants: b	Statistical measures: r[2]	Statistical measures: S_{yx}[3]
Silver maple	8	16	1.0 - 9.8	9.7 - 45.7	2.9 - 340.5	26.451	2.649	0.993	22
Sweet birch	10	17	1.9 - 8.8	10.1 - 46.4	5.2 - 340.8	19.670	3.091	0.962	40
Pignut hickory	10	16	0.9 - 16.2	10.1 - 65.4	3.5 - 256.6	25.311	3.099	0.992	30
American beech	8	14	1.5 - 13.5	15.4 - 54.9	9.5 - 127.9	32.372	2.869	0.995	16
Yellow-poplar	12	18	1.5 - 13.0	14.8 - 52.4	4.3 - 283.1	24.562	2.468	0.987	22
Scarlet oak	9	14	2.8 - 12.6	17.4 - 42.4	15.5 - 108.6	19.966	3.076	0.992	18

1/ Nomenclature given on page 35.
2/ Coefficient of correlation.
3/ Standard error of estimate in percent.

Because stem diameter at breast height (d_{bh}) is dependent to a considerable degree on stem form, any variations in the latter would tend to introduce errors in estimating dry weights of foliage, branchwood, and crown with equation (6). In an attempt to improve the accuracy of estimation and to avoid such errors, stem diameter at base of live crown (d_c) was used in place of d_{bh} in correlating the data (equation (7)). It was reasoned that such a substitution would correct for any variations in stem form which may have been present in the trees that were analyzed.

From the statistics presented in tables 2-4 it is apparent that the use of d_c in place of d_{bh} had both favorable and adverse affects on the accuracy of estimating dry weights of foliage, branchwood, and crown. It is interesting to note, however, that in the majority of cases, d_c did improve the accuracy of estimation to some degree, and where decreases were observed, the resulting standard errors of estimate were much the same as those obtained with d_{bh}. Correlating the data with d_c also gave higher degrees of correlation; this can be seen in comparing the coefficients of correlation (r) in tables 2-4.

Older trees or trees from poor sites generally have shorter and broader crowns. Because of this, dry weight estimations on foliage, branchwood, and crown for trees in this category are inclined to be high when calculated with equation (7). It was reasoned that with the inclusion of crown length in the dry weight relations (equation (8)), site and age affects on dry weight estimations would be minimized and the accuracy of estimation would be improved.

From the standard errors of estimate tabulated in table 2 it can be seen that the inclusion of H_c in the dry weight relation for foliage resulted in minor improvements in the accuracy of estimation. For some species the addition of H_c decreased the accuracy below that attainable with equation (7). In general, the foliage relations for a given species were comparable in accuracy regardless of the correlations used (see table 2). There were, however, two exceptions to be noted. In both silver maple and sweet birch marked differences in accuracy can be seen

in the foliage relations used to correlate the data of these two species. For silver maple foliage estimations were most accurately determined with the relation using height of crown. For sweet birch, however, the use of stem diameter at base of live crown without the height of crown variables gave the most accurate estimates. As in the case of d_c, inclusion of H_c resulted in higher foliage correlations for most species.

The accuracy of estimating dry weight of branchwood (table 3) was improved for most species when H_c was included in the correlation (equation (8)). Branchwood estimations for sweet birch, however, as in foliage estimations, were more accurately determined with equation (7). Yellow-poplar also gave better results with equation (7); however, in this case the accuracy of estimating dry weights differed only slightly from that of equation (8). For most species combining H_c with the branchwood data also resulted in higher degrees of correlation. This is evident from the coefficients of correlation calculated for the various species (see table 3).

In general, both equations (7) and (8) may be considered equally applicable in correlating dry branchwood data. In both cases higher degrees of correlation and greater accuracy were obtained for most species with these relations than with equation (6).

Dry weight estimations for total crown (table 4) were also found to be more accurately determined by equation (8) for most species. Furthermore, the inclusion of H_c in the correlation reduced the dispersion of the dry weight of crown data and in most cases resulted in higher degrees of correlation. It is interesting to note that the correlation for sweet birch exhibited poorer accuracy with the inclusion of H_c. Greater accuracy was found for this species by correlating crown weight with diameter at base of crown alone (see table 4). Similar results were also noted in the foliage and branchwood relations for this species (tables 2 and 3).

It should be pointed out at this time that rearrangement of the variables in equation (8) by combining H_c with d_c resulted in a slight loss in accuracy in estimating dry weights of foliage, branchwood, and crown. The arrangement of variables as presented in equation (8) gave better results for the species studied.

Before a correlation between drag force and dry weight of crown of trees of all sizes and all crown lengths can be established, it is necessary to demonstrate geometrical similarity of tree crowns. That is, for any given species the same relation between crown weight, crown length, and diameter at base of crown must be shown to hold for any portion of the tree crown. If tree crowns are geometrically similar, it can be assumed that wind forces will act on them similarly.

Examination of the equation constants calculated for the dry weight of crown relations of each species for trees with different crown sections (table 5) indicates that these relations are similar to those determined for full-crown trees (table 4). A marked tendency to parallelism can be seen in these relations for the various species. In addition, coefficients of correlation and standard errors of estimate are comparable. These similarities in correlation demonstrate the dry weight of crown relation, $W_{dc}H_c = a(d_c)^b$, is equally applicable for any portion of the tree crown regardless of tree size or crown length.

CONCLUSIONS

1. Dry weight of foliage, branchwood, and crown for six species of hardwoods are significantly related to diameter breast height (d_{bh}) and diameter base of live crown (d_c).
2. Using d_c in place of d_{bh} in the relations gave higher degrees of correlation for foliage, branchwood, and crown.
3. Combining height of crown (H_c) with dry weights of foliage, branchwood, and crown and correlating with d_c resulted in higher degrees of correlation for most species.
4. Foliage estimations can be determined with equal accuracy with each of the three relations developed in this study. Minor variations were found to exist in some species.
5. Branchwood estimations are least accurately determined with the relation $W_{db} = a(d_{bh})^b$; greater accuracy can be obtained with the relations $W_{db} = a(d_c)^b$ and $W_{db}H_c = a(d_c)^b$.

6. Crown weight estimations can be determined with greatest accuracy with the relation $W_{dc}H_c = a(d_c)^b$.
7. For the species studied, the relation for dry weight of crown, $W_{dc}H_c = a(d_c)^b$, is equally applicable for any portion of the tree crown regardless of tree size or crown length.
8. Dry weight of branchwood averaged 2-6 times heavier than dry weight of foliage in the six species of hardwoods studied.

APPENDIX

PHYSICAL CHARACTERISTICS OF SAMPLE TREES

Table 6.--Physical characteristics of sample trees[1]

Tree number	Species	d_{bh} (in.)	H_o (ft.)	Age (yrs.)	Percent crown	H_c (ft.)	d_c (in.)	W_{dc} (lbs.)	W_{db} (lbs.)	W_{df} (lbs.)
1	Silver maple	10.8	59.6	62	37	22.3	4.6	75.2	[2] 65.8	[2] 9.4
					55	32.8	7.1	167.1	[2] 146.2	[2] 20.9
					77	45.7	9.8	229.0	[2] 200.4	[2] 28.6
2	" "	12.9	67.3	68	27	18.1	4.1	43.6	[2] 34.3	[2] 9.3
					44	29.6	6.9	131.0	[2] 109.1	[2] 21.9
					62	41.6	8.9	228.9	[2] 196.4	[2] 32.5
3	" "	14.0	61.7	58	24	14.9	4.6	69.2	[2] 55.2	[2] 14.0
					38	23.2	8.0	248.8	[2] 208.1	[2] 40.7
					52	32.3	9.0	340.5	[2] 290.1	[2] 50.4
4	" "	2.2	33.5	25	29	9.7	1.0	2.9	2.6	0.3
					60	20.0	1.6	3.7	3.1	0.6
5	" "	11.7	60.2	41	31	18.7	5.0	104.2	[2] 82.8	[2] 21.4
					57	34.2	8.2	217.2	[2] 179.5	[2] 37.7
6	" "	5.3	54.3	32	34	18.4	2.0	14.2	12.9	1.3
7	" "	7.9	42.6	29	53	22.5	5.4	102.8	75.9	26.9
8	" "	6.9	40.2	40	60	24.3	4.9	83.9	68.7	15.2
9	Sweet birch	1.9	14.8	15	68	10.1	1.9	5.2	4.1	1.1
10	" "	7.2	65.6	38	39	25.7	3.9	66.2	[2] 54.8	[2] 11.4
					58	38.0	5.5	106.2	[2] 90.0	[2] 16.2
11	" "	8.3	65.9	38	31	20.7	3.2	42.6	[2] 33.5	[2] 9.1
					54	35.4	5.5	100.3	[2] 82.0	[2] 18.3
12	" "	3.8	48.8	31	51	24.8	2.4	20.3	17.4	2.9

1/ For definition of symbols see Nomenclature, page 35.
2/ Branchwood and foliage weights from samples.

Table 6 (continued)

Tree number	Species	d_{bh} (in.)	H_o (ft.)	Age (yrs.)	Percent crown	H_c (ft.)	d_c (in.)	W_{dc} (lbs.)	W_{db} (lbs.)	W_{df} (lbs.)
13	Sweet birch	12.5	77.6	-	38 57	29.2 44.0	5.0 8.8	160.8 316.7	[2] 134.5 [2] 272.4	[2] 26.3 [2] 44.3
14	" "	13.8	60.5	67	35 44 60	21.4 26.5 36.6	4.8 6.5 8.8	88.3 189.2 340.8	[2] 74.0 [2] 163.2 [2] 300.7	[2] 14.3 [2] 26.0 [2] 40.1
15	" "	11.2	70.4	56	37 48 66	25.7 33.7 46.4	4.0 6.1 8.2	65.4 186.1 282.7	[2] 57.5 [2] 168.9 [2] 255.4	[2] 7.9 [2] 17.2 [2] 27.3
16	" "	6.0	52.6	63	43	22.6	3.2	59.2	[2] 54.1	[2] 5.1
17	" "	7.7	53.9	29	40	21.5	3.5	35.3	27.6	7.7
18	" "	8.2	56.3	29	44	25.0	4.1	47.1	37.4	9.7
19	Pignut hickory	9.9	76.0	59	25 43	19.3 32.9	3.0 5.2	74.8 119.5	57.5 96.3	17.1 23.2
20	" "	1.9	25.4	24	40	10.1	0.9	3.5	2.9	0.6
21	" "	8.0	55.7	32	24 49	13.6 27.2	2.6 4.2	37.9 78.2	30.3 [2] 65.1	7.6 [2] 13.1
22	" "	3.5	32.4	35	38	12.4	1.9	11.1	9.6	1.5
23	" "	7.9	58.3	52	24 47	14.1 27.4	2.8 4.5	28.7 72.6	23.8 61.9	4.9 10.7
24	" "	6.3	50.9	51	51	26.1	3.2	23.3	18.7	4.6
25	" "	23.4	101.3	191	35 46 65	35.9 46.1 65.4	8.2 12.9 16.2	594.1 1563.6 2565.9	[2] 542.3 [2] 458.0 [2] 2394.8	[2] 51.8 [2] 105.6 [2] 171.2
26	" "	12.3	82.1	49	43 51	35.0 41.7	5.2 7.2	117.6 249.9	101.1 [2] 201.8	16.5 [2] 48.1

[2] Branchwood and foliage weights from samples.

Table 6 (continued)

Tree number	Species	d_{bh} (in.)	H_o (ft.)	Age (yrs.)	Percent crown	H_c (ft.)	d_c (in.)	W_{dc} (lbs.)	W_{db} (lbs.)	W_{df} (lbs.)
27	Pignut hickory	6.5	46.0	40	44	20.3	3.2	57.8	43.9	13.9
28	" "	6.3	41.9	42	55	23.2	3.5	62.0	51.7	10.3
29	American beech	7.9	58.2	43	48	27.8	5.0	106.6	2/ 93.5	2/ 13.1
					77	45.0	6.8	196.2	2/ 175.7	2/ 20.5
30	" "	5.8	47.5	51	42	20.1	3.2	40.4	34.6	5.8
					72	34.4	4.8	71.0	61.0	10.0
31	" "	9.6	60.3	62	37	22.4	4.0	3/ 71.2	2/ 59.4	2/ 11.8
					53	32.1	6.0	3/ 171.9	2/ 146.8	2/ 25.1
					79	47.7	8.2	3/ 255.8	2/ 221.6	2/ 34.2
32	" "	15.8	75.5	80	43	32.7	9.0	532.4	2/ 494.0	2/ 38.4
					57	43.3	12.2	1078.8	2/ 1008.2	2/ 70.6
					73	54.9	13.5	1279.2	2/ 1198.9	2/ 80.3
33	" "	2.4	26.6	20	58	15.4	1.5	9.5	8.1	1.4
34	" "	4.1	42.9	39	61	26.0	2.9	24.2	17.2	7.0
35	" "	5.7	39.2	32	65	25.3	4.2	64.8	56.1	8.7
36	" "	8.1	45.0	33	56	25.3	4.5	108.7	96.4	12.3
37	Yellow-poplar	4.9	50.8	27	39	19.6	3.1	16.6	15.0	1.6
38	" "	6.1	68.1	33	31	20.9	2.8	14.2	9.9	4.3
39	" "	2.9	36.2	20	54	19.4	1.9	5.9	4.6	1.3
40	" "	2.1	26.6	28	56	14.8	1.5	4.3	3.6	0.7
41	" "	8.3	76.8	32	32	24.7	3.6	34.6	27.9	6.7
					54	41.8	5.6	57.1	47.2	9.9
42	" "	12.6	88.5	43	21	19.0	4.0	34.8	25.8	9.0
					41	36.3	6.5	66.9	52.1	14.8

2/ Branchwood and foliage weights from samples.
3/ Crown weights from samples.

Table 6 (continued)

Tree number	Species	d_{bh} (in.)	H_o (ft.)	Age (yrs.)	Percent crown	H_c (ft.)	d_c (in.)	W_{dc} (lbs.)	W_{db} (lbs.)	W_{df} (lbs.)
43	Yellow-poplar	21.6	99.1	60	25	24.5	7.9	90.5	2/ 73.1	2/ 17.4
					49	48.8	13.0	283.1	2/ 246.2	2/ 36.9
44	" "	10.5	84.9	46	29	24.5	3.6	25.8	20.4	5.4
					52	44.1	6.5	58.0	48.3	9.7
45	" "	14.6	93.8	50	21	19.9	3.9	39.6	2/ 30.9	2/ 8.7
					37	34.6	6.6	89.3	2/ 71.6	2/ 17.7
					56	52.4	9.0	125.9	2/ 104.3	2/ 21.6
46	" "	8.2	61.1	32	38	23.4	3.7	24.4	16.3	8.1
47	" "	9.1	51.4	33	47	24.1	4.9	56.2	42.4	8.1
48	" "	6.9	38.2	31	63	24.0	4.5	35.2	23.6	11.6
49	Scarlet oak	8.0	50.4	32	35	17.4	3.2	50.1	2/ 38.8	2/ 11.3
					58	29.4	5.2	126.0	2/ 103.7	2/ 22.3
50	" "	11.8	72.9	64	30	22.2	4.1	71.0	2/ 59.8	2/ 11.2
					46	33.4	5.9	173.1	2/ 145.7	2/ 27.4
					49	35.5	7.1	244.1	2/ 205.5	2/ 38.6
51	" "	14.3	81.1	64	31	25.5	5.6	195.5	2/ 175.5	2/ 20.0
					45	36.1	8.6	466.7	2/ 418.9	2/ 47.8
52	" "	4.1	43.6	-	47	20.5	2.8	15.5	2/ 13.0	2/ 2.5
53	" "	20.2	91.8	104	35	32.3	10.0	521.1	2/ 461.5	2/ 59.6
					46	42.4	12.6	1086.0	2/ 979.3	2/ 106.7
54	" "	5.8	53.1	36	35	18.8	3.0	33.7	26.3	7.4
55	" "	7.6	49.9	44	45	22.6	3.8	46.6	36.1	10.5
56	" "	9.0	60.4	39	37	22.3	4.0	58.6	45.7	12.9
57	" "	9.6	53.3	31	44	23.2	4.2	71.6	53.2	18.4

2/ Branchwood and foliage weights from samples.

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NOMENCLATURE

a = constant in regression equations

b = coefficient in regression equations

bh = breast height, 4.5 ft. above ground level

d_{bh} = stem diameter outside bark at breast height, ft.

d_c = stem diameter inside bark at base of live crown, in.

H_{bh} = height of stem above breast height, ft.

H_c = height of crown or crown length, ft.

H_o = total height of tree from the beginning of the current year's growth at the tip to 1 ft. above ground level, ft.

k = W_{df}/W_{db}, dry weight ratio of foliage to branchwood from section sample

M_b = moisture content of branchwood in crown section, oven-dried weight basis

M_f = moisture content of foliage in crown section, oven-dried weight basis

m = moisture content of foliage or branchwood in section sample, oven-dried weight basis

r = coefficient of correlation

S_{yx} = standard error of estimate, percent

W = dry weight of foliage, branchwood, or crown in a given tree, lbs.

W_{db} = dry weight of branchwood in a given tree, lbs.

W_{dc} = $W_{df} + W_{db}$, dry weight of crown in a given tree, lbs.

W_{df} = dry weight of foliage in a given tree, lbs.

W'_{db} = dry weight of branchwood in a crown section, lbs.

W'_{df} = dry weight of foliage in a crown section, lbs.

W'_{gc} = weight of green crown in a crown section, lbs.

w_d = dry weight of foliage or branchwood in section sample, lbs.

w_{db} = dry weight of branchwood in section sample, lbs.

w_{df} = dry weight of foliage in section sample, lbs.

w_g = weight of green foliage or green branchwood in section sample, lbs.

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